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(54) **SQUEEZE FILM DAMPER**

SQUEEZE-FILM DÄMPFER

AMORTISSEUR À FILM D'HUILE

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Description

Field

[0001] The disclosure relates generally to gas turbine engines, and more particularly to damping devices within gas turbine engine bearing compartments.

Background

[0002] Gas turbine engines typically comprise bearings which support rotating shafts. The bearings may comprise an inner race which rotates with the shaft, and a plurality of rollers between the inner race and an outer race which does not rotate. One or more seals may contain an annulus between the outer race and a housing. Oil may be fed into the annulus. The oil may form a squeeze film damper which damps whirling of the shaft, in which the shaft deflects away from an engine centerline and precesses about the engine centerline. However, under certain conditions, the squeeze film damper may degrade in its ability to damp rotor motion, an effect known as "oil inertia." In such conditions, prior methods have involved turning the supply of oil to the squeeze film damper off with an external valve, rendering the squeeze film damper ineffective.

[0003] A prior art bearing for a shaft having the features of the preamble to claim 1 is disclosed in US 2011/0064340. Other prior art bearings are disclosed in WO 98/26190 and GB 1 284 602.

Summary

[0004] From one aspect, the present invention provides a bearing for a shaft in accordance with claim 1.

[0005] From another aspect, the present invention provides a squeeze film damper in accordance with claim 3.

[0006] From yet another aspect, the present invention provides a gas turbine engine in accordance with claim 5.

[0007] Features of embodiments are recited in the dependent claims.

[0008] The foregoing features and elements may be combined in various combinations without exclusivity, unless expressly indicated otherwise. These features and elements as well as the operation thereof will become more apparent in light of the following description and the accompanying drawings. It should be understood, however, the following description and drawings are intended to be exemplary in nature and non-limiting.

Brief Description of the Drawings

[0009] The subject matter of the present disclosure is particularly pointed out and distinctly claimed in the concluding portion of the specification. A more complete understanding of the present disclosure, however, may best be obtained by referring to the detailed description and claims when considered in connection with the drawing figures.

FIG. 1 illustrates a schematic cross-section view of a gas turbine engine in accordance with various embodiments;

FIG. 2 illustrates a cross-section view of a bearing in accordance with various embodiments;

FIG. 3 illustrates a cross-section view of a bearing and damper pressure profile along the engine centerline in accordance with various embodiments;

FIG. 4 illustrates a cross-section view of a bearing and damper pressure profile having a housing with a roughened surface along the engine centerline in accordance with various embodiments; and

FIG. 5 illustrates a cross-section view of an annulus in accordance with various embodiments.

Detailed Description

[0010] The detailed description of various embodiments herein makes reference to the accompanying drawings, which show various embodiments by way of illustration. While these various embodiments are described in sufficient detail to enable those skilled in the art to practice the disclosure, it should be understood that other embodiments may be realized and that logical, chemical, and mechanical changes may be made without departing from the scope of the disclosure. Thus, the detailed description herein is presented for purposes of illustration only and not of limitation. For example, the steps recited in any of the method or process descriptions may be executed in any order and are not necessarily limited to the order presented. Furthermore, any reference to singular includes plural embodiments, and any reference to more than one component or step may include a singular embodiment or step. Also, any reference to attached, fixed, connected, or the like may include permanent, removable, temporary, partial, full, and/or any other possible attachment option. Additionally, any reference to without contact (or similar phrases) may also include reduced contact or minimal contact.

[0011] Referring to FIG. 1, a gas turbine engine 100 (such as a turbofan gas turbine engine) is illustrated according to various embodiments. Gas turbine engine 100 is disposed about engine centerline 120, which may also be referred to as axis of rotation 120. Gas turbine engine 100 may comprise a fan 140, compressor sections 150 and 160, a combustion section 180 including a combustor, and turbine sections 190, 191. Air compressed in the compressor sections 150, 160 may be mixed with fuel and burned in combustion section 180 and expanded across the turbine sections 190, 191. The turbine sections 190, 191 may include high pressure rotors 192 and low pressure rotors 194, which rotate in response to the expansion. The turbine sections 190, 191 may comprise alternating rows of rotary airfoils or blades 196 and static airfoils or vanes 198. Cooling air may be supplied to the combustor and turbine sections 190, 191 from the com-

pressor sections 150, 160. A plurality of bearings 115 may support spools in the gas turbine engine 100. FIG. 1 provides a general understanding of the sections in a gas turbine engine, and is not intended to limit the disclosure. The present disclosure may extend to all types of rotating machinery, turbomachinery, and pumps, including turbofan gas turbine engines and turbojet engines, for all types of applications. This may also extend when used in combination with other bearing types in said applications including journal type bearings.

[0012] The forward-aft positions of gas turbine engine 100 lie along axis of rotation 120. For example, fan 140 may be referred to as forward of turbine section 190 and turbine section 190 may be referred to as aft of fan 140. Typically, during operation of gas turbine engine 100, air flows from forward to aft, for example, from fan 140 to turbine section 190. As air flows from fan 140 to the more aft components of gas turbine engine 100, axis of rotation 120 may also generally define the direction of the air stream flow.

[0013] Referring to FIG. 2, a cross-section view of a bearing 200 is illustrated according to various embodiments. The bearing 200 may comprise an inner race 210, a roller 220, and an outer race 230. The inner race 210 may be coupled to a shaft 240 which rotates about the engine centerline 120. The inner race 210 may rotate with the shaft 240. The outer race 230 may not rotate with the inner race 210. The roller 220 may rotate and decrease friction between the inner race 210 and the outer race 230 as the inner race 210 rotates relative to the outer race 230. The bearing 200 may be located within a housing 250. The housing 250 and the outer race 230 may form an annulus 260 around the outer race 230 and between the outer race 230 and the housing 250. The housing 250 may comprise a roughened surface 251, as further described with reference to FIG. 4 and FIG. 5. The annulus 260 may be at least partially sealed by seals 270. Oil may be supplied to the annulus 260 through an oil supply hole 255 in the housing 250. The oil may absorb heat from the outer race 230. A portion of the oil, heated by the shearing of the oil in the annulus 260, may leak by the seals 270, and additional, cooler oil may be supplied to the annulus 260 through the oil supply hole 255.

[0014] Referring to FIG. 3, a cross-section view of a prior art bearing 300 looking along the engine centerline with the shaft whirling is illustrated according to various embodiments. The shaft assembly 340 (which may include the shaft, the inner race, the rollers, and the outer race) may be displaced from the engine centerline 120 by the displacement D. The shaft assembly 340 may whirl about the engine centerline 120 as indicated by the rotational velocity vector ω. The whirling motion may squeeze oil around the annulus 360, producing a rotating pressure wave P. The pressure wave P may comprise a stiffness force Fs along the direction of displacement D and in the opposite direction of the displacement D. The stiffness force F_s may resist displacement of the shaft assembly 340. The pressure wave P may comprise a damping force F_d orthogonal to the direction of displacement D and opposite to the direction of the whirl velocity vector ω. The damping force F_d may thus decrease the amplitude of the whirling motion. The pressure wave P may be altered by changing parameters including the annulus diameter, the annulus length, the clearance between the outer race and the housing, and the oil viscosity.

[0015] Referring to FIG. 4, a cross-section view of the bearing 200 comprising a roughened housing surface looking along the engine centerline 120 is illustrated according to various embodiments. The housing 250 comprises a roughened surface 251. The roughened surface 251 increases the friction between the housing 250 and the oil in the annulus 260. The increased friction may have a similar effect to increasing the viscosity of the oil and/or decreasing the Reynolds number in the bearing 200. As the shaft assembly 440 (which may include the shaft, the inner race, the rollers, and the outer race) whirls about the engine centerline 120, the shaft assembly 440 may tend to push the oil in front of the direction of whirl ω of the shaft assembly 440 around the annulus 260. The roughened surface 251 may increase resistance to the oil squeezing around the annulus 260 ahead of the direction of whirl of the shaft assembly. Thus, the roughened surface 251 may shift the pressure wave P circumferentially in the direction of whirl of the shaft assembly 440. This may increase the ratio of the damping force F_d to the stiffness force F_s. The increased ratio may prevent the effects of oil inertia and allow the squeeze film damper to be utilized over a larger operating range of the engine.

[0016] Referring to FIG. 5, a cross section view of the annulus 260 is illustrated according to various embodiments. The annulus 260 may be defined by the outer race 230, the housing 250, and the seals 270. The housing 250 comprises a roughened surface 251. The roughened surface 251 comprises surface features 252. The surface features 252 may be any shape or pattern which increases friction between the outer race 230 and oil within the annulus 260. In various embodiments, the surface features 252 may comprise at least one of grooves, posts, dots, swirls, a herringbone pattern, cross-hatch, honeycomb, dimples, flaps, teeth, etc.

[0017] The surface features 252 comprise a height H. The height H may be expressed as a ratio of the clearance C between the outer race 230 and the housing 250. In accordance with the present invention, the height H is 10-20% of the clearance C. In various embodiments, the clearance C may be between .005 inches - .025 inches (.01 cm - .06 cm). In various embodiments, the height H may be between .0005 inches - .005 inches (.001 cm - .01 cm). In various embodiments, the roughened surface 251 may comprise a surface roughness of greater than 20 R_A microinches (0.51 micrometers). In various embodiments, the roughened surface 251 may comprise a surface roughness of greater than 50 R_A microinches (1.3 micrometers).

[0018] The roughened surface 251 may be formed by any process suitable to roughen the housing 250. In various embodiments, the housing 250 may be formed with the roughened surface 251. In various embodiments, the housing 250 may be formed with a smooth surface, and the roughened surface 251 may be formed by grinding, etching, carving, scraping, or otherwise removing material from the housing 250. In various embodiments, the roughened surface 251 may be formed by coupling the surface features 252 to the housing 250, such as by spraying on the surface features 252 or coupling a roughened sleeve to the housing 250.

[0019] Benefits, other advantages, and solutions to problems have been described herein with regard to specific embodiments. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in a practical system. However, the benefits, advantages, solutions to problems, and any elements that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as critical, required, or essential features or elements of the disclosure. The scope of the disclosure is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." Moreover, where a phrase similar to "at least one of A, B, or C" is used in rather "one or more." Moreover, where a phrase similar to "at least one of A, B, or C" is used in the claims, it is intended that the phrase be interpreted to mean that A alone may be present in an embodiment, B alone may be present in an embodiment, C alone may be present in an embodiment, or that any combination of the elements A, B and C may be present in a single embodiment; for example, A and B, A and C, B and C, or A and B and C. Different cross-hatching is used throughout the figures to denote different parts but not necessarily to denote the same or different materials.

[0020] Systems, methods and apparatus are provided herein. In the detailed description herein, references to "one embodiment", "an embodiment", "various embodiments", etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. After reading the description, it will be apparent to one skilled in the relevant art(s) how to implement the disclosure in alternative embodiments.

Claims

1. A bearing (230) for a shaft (240) comprising:

   an inner race (210) configured to couple to the shaft (240);
   an outer race (230) disposed around the inner race (210); and
   a housing (250) disposed around the outer race (230), wherein the housing (250) and the outer race (230) define an annulus (260); and **characterised in that**
   the housing (250) comprises a roughened surface (251) comprising a plurality of surface features (252) having a height between 10-20% of a clearance between the housing (250) and the outer race (230).

2. The bearing of claim 1, further comprising a seal (270) between the outer race (230) and the housing (250).

3. A squeeze film damper comprising:

   the bearing of claim 1; and
   a first seal (270) and a second seal (270) between the outer race (230) and the housing (250); wherein the housing (250), the outer race (230), the first seal (270) and the second seal (270) define the annulus (260).

4. The squeeze film damper of claim 3, further comprising an oil supply hole (255) in the housing (250).

5. A gas turbine engine (100) comprising:

   a shaft (240);
   the bearing of claim 1 or 2 coupled to the shaft (240);
   wherein the shaft (240) and the inner bearing race (210) are configured to rotate within the outer bearing race (230); and
   wherein the outer bearing race (230) is configured to whirl within the housing (250).

6. The bearing, squeeze film damper or gas turbine engine of any preceding claim, wherein the plurality of surface features (252) comprise at least one of grooves, posts, dots, swirls, a herringbone pattern, cross-hatch, honeycomb, dimples, flaps, or teeth.

7. The bearing, squeeze film damper or gas turbine engine of any preceding claim, wherein the roughened surface (251) comprises a surface roughness of at least 50 R_A microinches (1.3 μm).

Patentansprüche

1. Lager (230) für eine Welle (240), umfassend:

   einen Innenring (210), der konfiguriert ist, um an die Welle (240) zu koppeln;
   einen Außenring (230), der um den Innenring (210) herum angeordnet ist; und
   ein Gehäuse (250), das um den Außenring (230) herum angeordnet ist, wobei das Gehäuse (250) und der Außenring (230) einen Kranz (260) definieren; und **dadurch gekennzeichnet, dass** das Gehäuse (250) eine aufgeraute Oberfläche (251) umfasst,
   die eine Vielzahl von Oberflächenmerkmalen (252) umfasst, die eine Höhe zwischen 10-20 % eines Spielraums zwischen dem Gehäuse (250) und dem Außenring (230) aufweist.

2. Lager nach Anspruch 1, ferner umfassend eine Dichtung (270) zwischen dem Außenring (230) und dem Gehäuse (250).

3. Squeeze-Film-Dämpfer, umfassend:

   das Lager nach Anspruch 1; und
   eine erste Dichtung (270) und eine zweite Dichtung (270) zwischen dem Außenring (230) und dem Gehäuse (250); wobei das Gehäuse (250), der Außenring (230), die erste Dichtung (270) und die zweite Dichtung (270) den Kranz (260) definieren.

4. Squeeze-Film-Dämpfer nach Anspruch 3, ferner umfassend ein Ölzufuhrloch (255) in dem Gehäuse (250).

5. Gasturbinenmotor (100), umfassend:

   eine Welle (240);
   das Lager nach Anspruch 1 oder 2, das an die Welle (240) gekoppelt ist;
   wobei die Welle (240) und der Innenlagerring (210) konfiguriert sind, um sich innerhalb des Außenlagerrings (230) zu drehen; und
   wobei der Außenlagerring (230) konfiguriert ist, um innerhalb des Gehäuses (250) zu wirbeln.

6. Lager, Squeeze-Film-Dämpfer oder Gasturbinenmotor nach einem vorhergehenden Anspruch, wobei die Vielzahl von Oberflächenmerkmalen (252) zumindest eines von Nuten, Pfosten, Punkten, Wirbeln, einem Fischgrätenmuster, Kreuzschraffur, Waben, Vertiefungen, Laschen oder Zähnen umfasst.

7. Lager, Squeeze-Film-Dämpfer oder Gasturbinenmotor nach einem vorhergehenden Anspruch, wobei die aufgeraute Oberfläche (251) eine Oberflächenrauigkeit von zumindest $50R_A$ Mikrozoll (1,3 μm) umfasst.

Revendications

1. Palier (230) pour un arbre (240) comprenant :

   une bague intérieure (210) configurée pour se coupler à l'arbre (240) ;
   une bague extérieure (230) disposée autour de la bague intérieure (210) ; et
   un logement (250) disposé autour de la bague extérieure (230),
   dans lequel le logement (250) et la bague extérieure (230) définissent un anneau (260) ; et **caractérisé en ce que** le logement (250) comprend une surface rugueuse (251) comprenant une pluralité de caractéristiques de surface (252) ayant une hauteur comprise entre 10 et 20 % d'un espacement entre le logement (250) et la bague extérieure (230).

2. Palier selon la revendication 1, comprenant en outre un joint d'étanchéité (270) entre la bague extérieure (230) et le logement (250).

3. Amortisseur à film d'huile comprenant :

   le palier de la revendication 1 ; et
   un premier joint d'étanchéité (270) et un second joint d'étanchéité (270) entre la bague extérieure (230) et le logement (250) ; dans lequel le logement (250), la bague extérieure (230), le premier joint d'étanchéité (270) et le second joint d'étanchéité (270) définissent l'anneau (260).

4. Amortisseur à film d'huile selon la revendication 3, comprenant en outre un trou d'alimentation en huile (255) dans le logement (250).

5. Moteur à turbine à gaz (100) comprenant :

   un arbre (240) ;
   le palier de la revendication 1 ou 2 couplé à l'arbre (240) ;
   dans lequel l'arbre (240) et la bague de palier intérieure (210) sont configurés pour tourner à l'intérieur de la bague de palier extérieure (230) ; et
   dans lequel la bague de palier extérieure (230) est configurée pour tourbillonner à l'intérieur du logement (250).

6. Palier, amortisseur à film d'huile ou moteur à turbine à gaz selon une quelconque revendication précédente, dans lequel la pluralité de caractéristiques de

surface (252) comprend au moins l'un de rainures, de montants, de points, de tourbillons, d'un motif en chevrons, d'un hachurage croisé, d'un nid d'abeilles, de crans d'arrêt, de trappes ou de dents.

7. Palier, amortisseur à film d'huile ou moteur à turbine à gaz selon une quelconque revendication précédente, dans lequel la surface rugueuse (251) comprend une rugosité de surface d'au moins 50 micropouces R_A (1,3 μm).

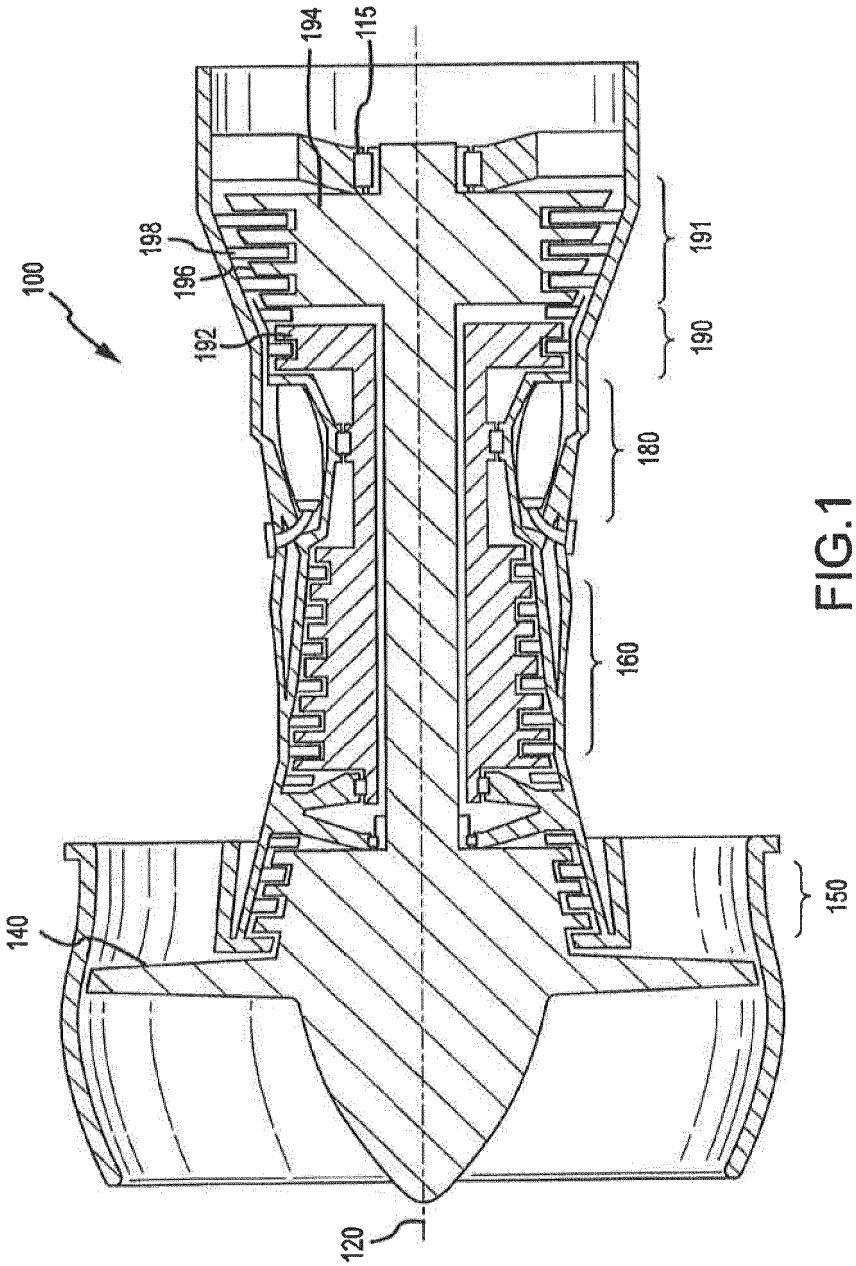

FIG.1

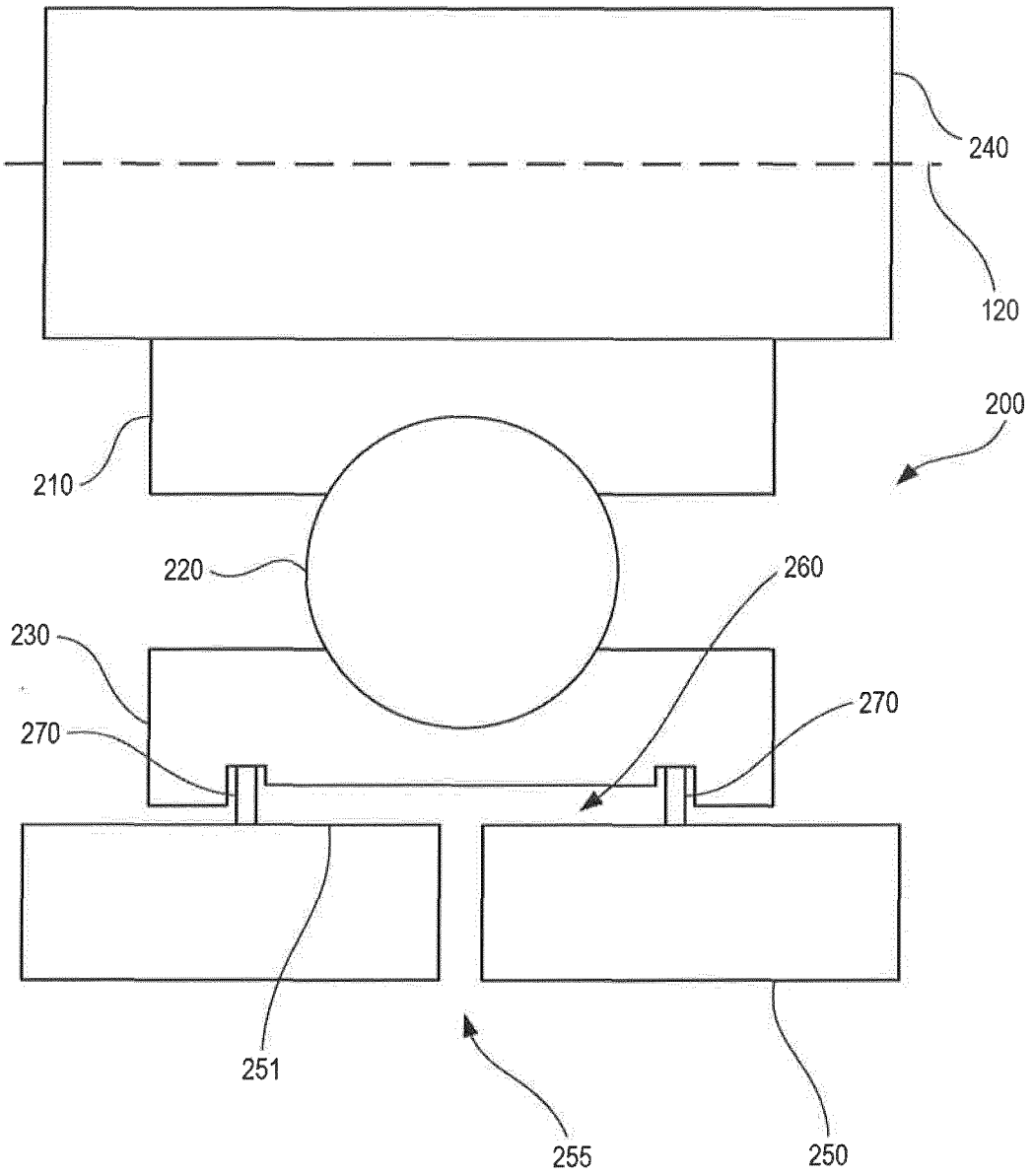

FIG. 2

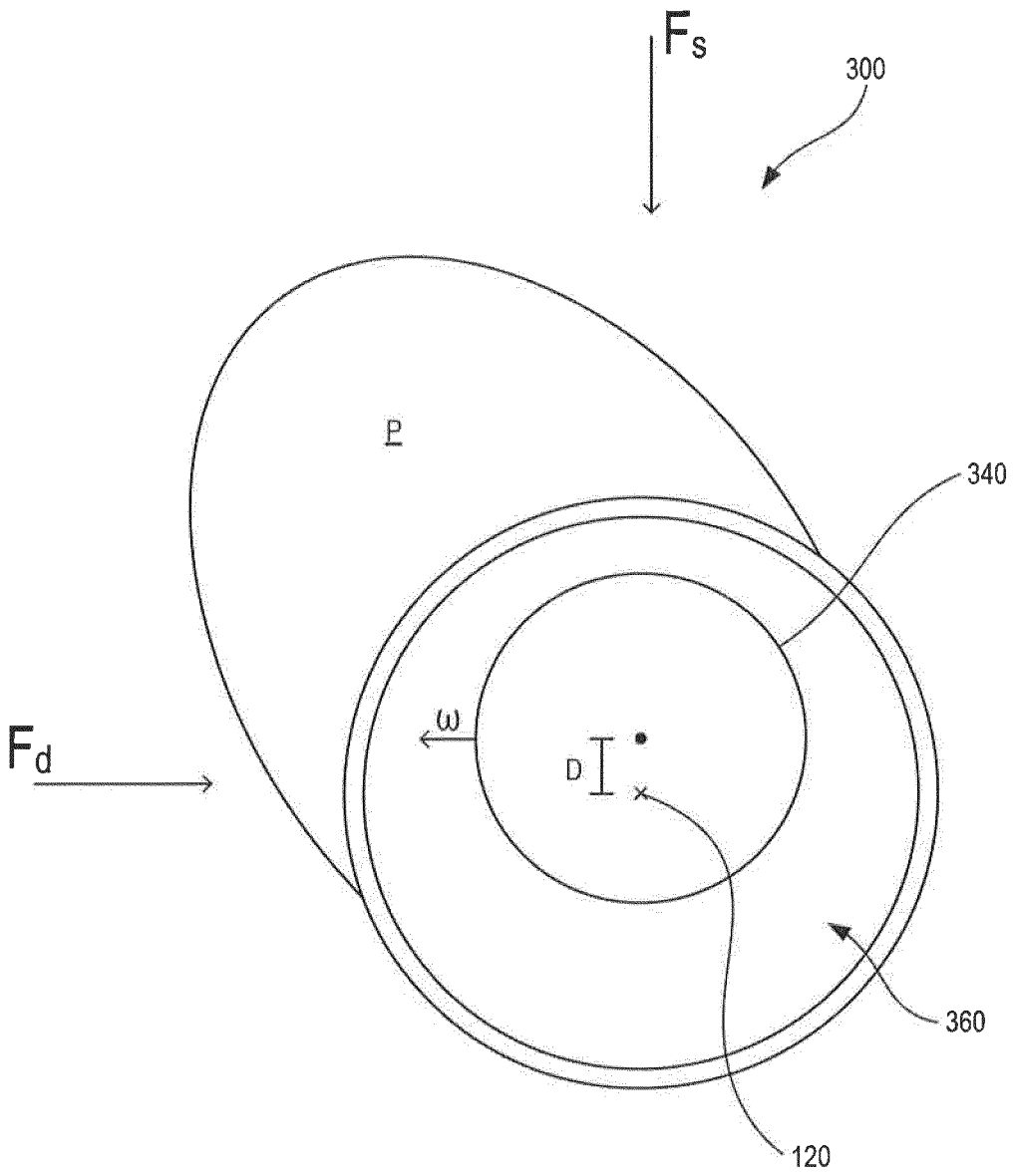

FIG. 3
(Prior Art)

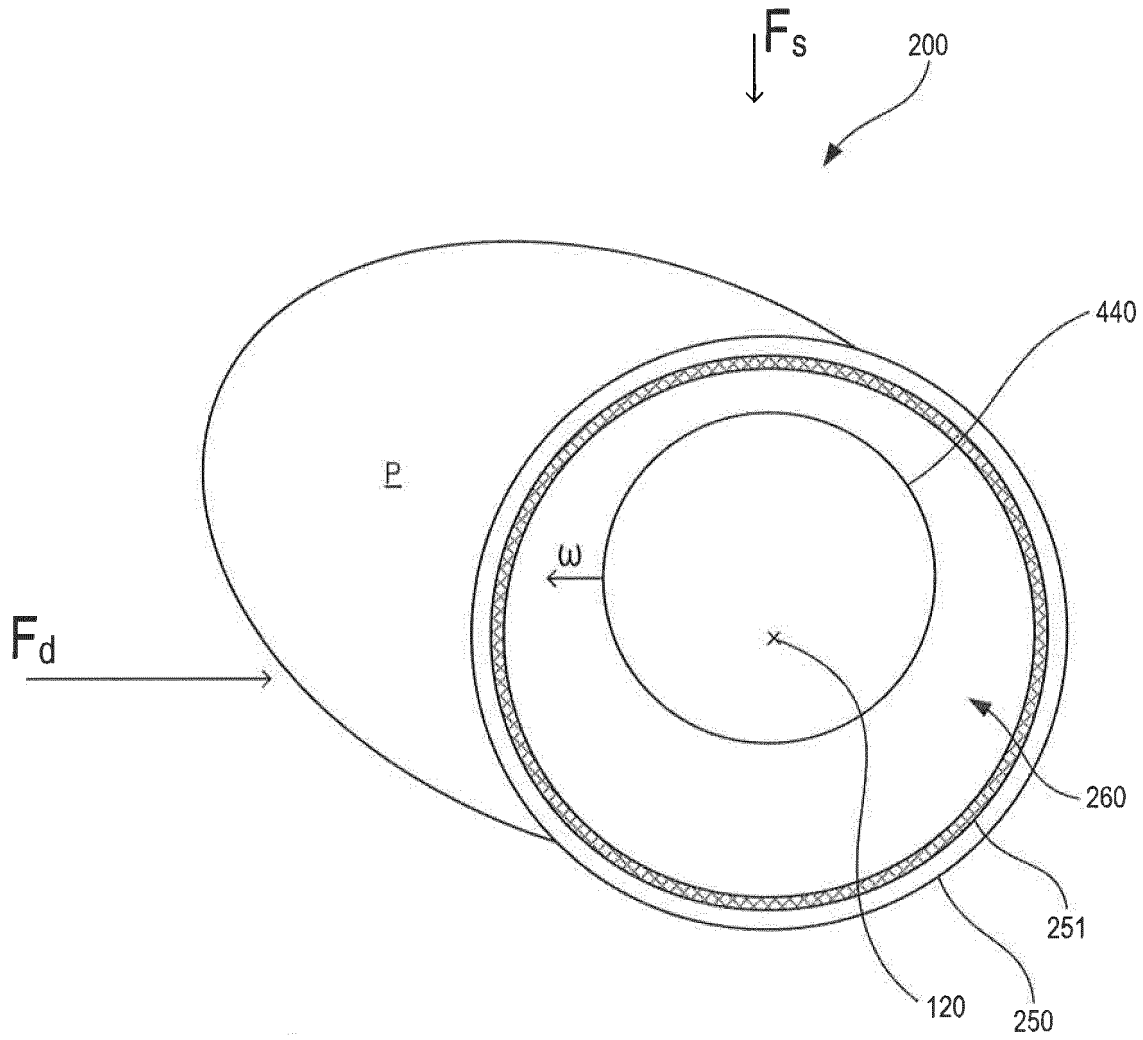

FIG. 4

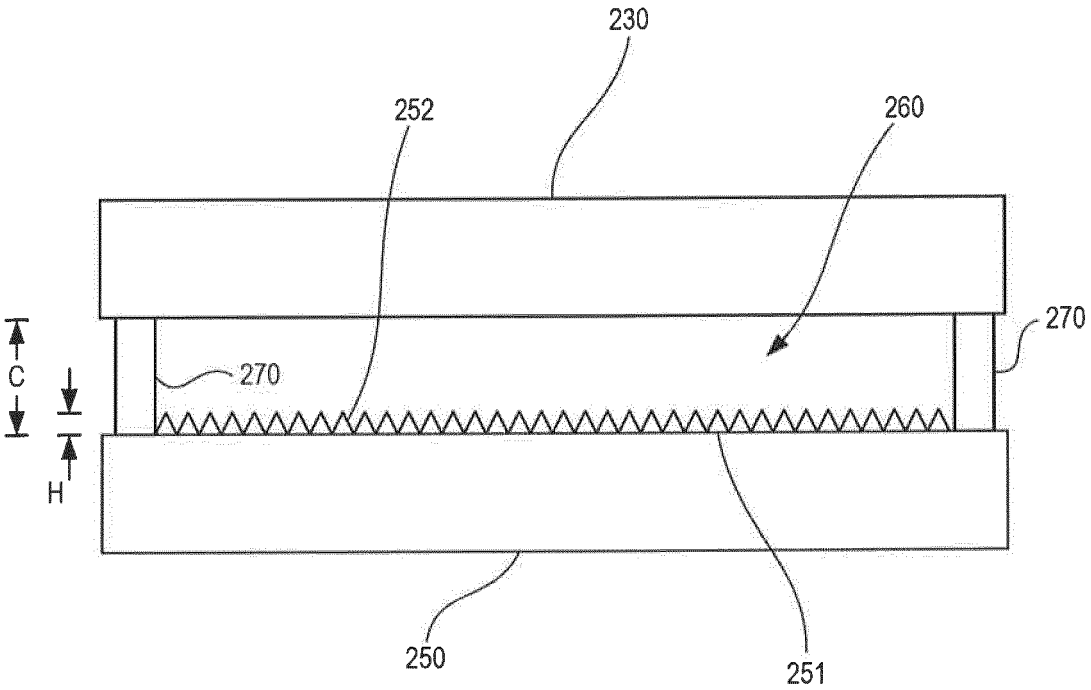

FIG. 5

REFERENCES CITED IN THE DESCRIPTION

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